CLAIMS

1. A microreactor for obtaining hydrogen gas by reforming a feed material, characterized by comprising:

a metal substrate having a microchannel portion on one surface thereof, a heater provided on the other surface of said metal substrate via an insulating film, a catalyst supported on said microchannel portion, and a cover member having a feed material inlet and a gas outlet and joined to said metal substrate so as to cover said microchannel portion.

2. A microreactor according to claim 1, wherein said metal substrate is one of an Al substrate, a Cu substrate, and a stainless substrate.

3. A microreactor according to claim 1, wherein said insulating film is a metal oxide film formed by anodically oxidizing said metal substrate.

4. A microreactor according to claim 3, wherein said metal oxide film is also provided in said microchannel portion.

5. A microreactor according to claim 4, wherein said metal substrate is an Al substrate.

6. A microreactor according to claim 1, wherein a heater protective layer is provided so as to cover said heater while exposing only electrodes of said heater.

7. A production method of a microreactor for obtaining hydrogen gas by reforming a feed material, characterized by comprising:

a step of forming a microchannel portion on one surface of a metal substrate;

a step of anodically oxidizing said metal substrate to form an insulating film in the form of a metal oxide film;

a step of providing a heater on said metal oxide film on a surface, where said microchannel portion is not formed, of said metal substrate;

a step of applying a catalyst to said microchannel portion; and

a step of joining a cover member formed with a feed material inlet and a gas outlet to said metal substrate so as to cover said microchannel portion.

8. A production method of a microreactor for obtaining hydrogen gas by reforming a feed material, characterized by comprising:

a step of forming a microchannel portion on one surface of a metal substrate;

a step of providing an insulating film on a

surface, where said microchannel portion is not formed, of said metal substrate;

a step of providing a heater on said insulating film;

a step of applying a catalyst to said microchannel portion; and

a step of joining a cover member formed with a feed material inlet and a gas outlet to said metal substrate so as to cover said microchannel portion.

9. A microreactor for obtaining hydrogen gas by reforming a feed material, characterized in that:

a plurality of metal substrates each having on one surface thereof a microchannel portion carrying a catalyst are stacked in multi-steps so that the surfaces where said microchannel portions are formed are oriented in the same direction, said metal substrates are provided with through holes, respectively, for communication between said microchannel portions of the metal substrates in the respective steps, at least one of said metal substrates is provided with a heater that is disposed, via an insulating film, on a surface where said microchannel portion is not formed, and a cover member having a gas outlet is joined to said metal substrate located at an outermost position of the multi-steps and exposing said microchannel portion.

10. A microreactor according to claim 9, wherein said

metal substrate is one of an Al substrate, a Cu substrate, and a stainless substrate.

11. A microreactor according to claim 9, wherein said insulating film is a metal oxide film formed by anodically oxidizing said metal substrate.

12. A microreactor according to claim 11, wherein said metal oxide film is also provided in said microchannel portion.

13. A microreactor according to claim 12, wherein said metal substrate is an Al substrate.

14. A microreactor according to claim 9, wherein said heater is provided on the metal substrate located at an outermost position of the multi-steps, and a heater protective layer is provided so as to cover said heater while exposing electrodes of said heater and an opening of the through hole of said metal substrate.

15. A microreactor according to claim 9, wherein said metal substrates are in a two-step stacked structure with the two metal substrates, and wherein the first step carries out mixing of feed materials, vaporization of a mixed feed material, and reforming of mixture gas, and the second step carries out removal of impurities from reformed

gas.

16. A production method of a microreactor for obtaining hydrogen gas by reforming a feed material, characterized by comprising:

a step of forming, on one surface of each of a plurality of metal substrates, a microchannel portion and a through hole having an opening at a predetermined position of said microchannel portion;

a step of anodically oxidizing said metal substrates to form insulating films each in the form of a metal oxide film;

a step of providing a heater on said metal oxide film on a surface, where said microchannel portion is not formed, of at least one of said metal substrates;

a step of applying catalysts to the microchannel portions of said plurality of metal substrates;

a step of removing said metal oxide film at a portion subjected to joining when said plurality of metal substrates are stacked in multi-steps; and

a step of joining together said plurality of metal substrates so as to be stacked in multi-steps such that the microchannel portions of said metal substrates communicate with each other via said through holes, and joining a cover member formed with a gas outlet to said metal substrate located at an outermost position of the multi-steps and exposing said microchannel portion.

17. A production method of a microreactor for obtaining hydrogen gas by reforming a feed material, characterized by comprising:

a step of forming, on one surface of each of a plurality of metal substrates, a microchannel portion and a through hole having an opening at a predetermined position of said microchannel portion;

a step of providing an insulating film on a surface, where said microchannel portion is not formed, of each of said metal substrates;

a step of providing a heater on said insulating film of at least one of said metal substrates;

a step of applying catalysts to the microchannel portions of said plurality of metal substrates; and

a step of joining together said plurality of metal substrates so as to be stacked in multi-steps such that the microchannel portions of said metal substrates communicate with each other via said through holes, and joining a cover member formed with a gas outlet to said metal substrate located at an outermost position of the multi-steps and exposing said microchannel portion.

18. A microreactor for obtaining hydrogen gas by reforming a feed material, characterized by comprising:

a joined body comprising a metal substrate provided with a microchannel portion on one surface thereof,

and a metal cover member having a feed material inlet and a gas outlet and joined to said metal substrate so as to cover said microchannel portion, a flow path formed by said microchannel portion located inside said joined body and said metal cover member, and a catalyst supported on a whole inner wall surface of said flow path.

19. A microreactor according to claim 18, wherein said flow path has no angular portion on the inner wall surface along a fluid flow direction.

20. A microreactor according to claim 18, wherein the catalyst is supported on the inner wall surface of said flow path via a metal oxide film.

21. A microreactor according to claim 20, wherein said metal oxide film is formed by anodic oxidation of said metal substrate and said metal cover member.

22. A microreactor according to claim 20, wherein said metal oxide film is formed by a boehmite treatment.

23. A microreactor according to claim 18, wherein said metal substrate is provided with a heater on a surface opposite to the surface where said microchannel portion is formed, via an insulating film.

24. A microreactor for obtaining hydrogen gas by reforming a feed material, characterized by comprising:

a joined body formed by joining together a pair of metal substrates each having a microchannel portion on one surface thereof and having patterns of said microchannel portions that are in a plane symmetrical relationship to each other, such that said microchannel portions confront each other, a flow path formed by said microchannel portions confronting each other inside said joined body, a catalyst supported on a whole inner wall surface of said flow path, a feed material inlet located at one end portion of said flow path, and a gas outlet located at the other end portion of said flow path.

25. A microreactor according to claim 24, wherein said flow path has no angular portion on the inner wall surface along a fluid flow direction, and the shape of the inner wall surface in a section perpendicular to the flow direction of the flow path is generally circular or oval.

26. A microreactor according to claim 24, wherein the catalyst is supported on the inner wall surface of said flow path via a metal oxide film.

27. A microreactor according to claim 26, wherein said metal oxide film is formed by anodic oxidation of said metal substrates.

28. A microreactor according to claim 26, wherein said metal oxide film is formed by a boehmite treatment.

29. A microreactor according to claim 24, wherein at least one of said metal substrates is provided with a heater on a surface opposite to the surface where said microchannel portion is formed, via an insulating film.

30. A production method of a microreactor for obtaining hydrogen gas by reforming a feed material, characterized by comprising:

a channel portion forming step of forming a microchannel portion on one surface of a metal substrate;

a joining step of joining a metal cover member having a feed material inlet and a gas outlet to said metal substrate so as to cover said microchannel portion to thereby form a joined body having a flow path;

a surface processing step of forming a metal oxide film on an inner wall surface of said flow path; and

a catalyst applying step of applying a catalyst to the inner wall surface of said flow path via said metal oxide film.

31. A production method of a microreactor according to claim 30, wherein said surface processing step forms said metal oxide film by anodically oxidizing said metal

substrate and said metal cover member.

32. A production method of a microreactor according to claim 30, wherein said surface processing step forms said metal oxide film by a boehmite treatment.

33. A production method of a microreactor according to claim 30, wherein said channel portion forming step forms said microchannel portion on said metal substrate such that a section thereof becomes U-shaped or semicircular, and no angular portion exists on a wall surface along a flow direction.

34. A production method of a microreactor according to claim 30, wherein said catalyst applying step fills the flow path of said joined body with a catalyst suspension, then removes said catalyst suspension and dries the inside of the flow path.

35. A production method of a microreactor according to claim 34, wherein said catalyst applying step gives vibration or rotation to said joined body upon drying.

36. A production method of a microreactor for obtaining hydrogen gas by reforming a feed material, characterized by comprising:

a channel portion forming step of forming

microchannel portions with patterns that are plane-symmetrical with each other, on either surfaces of a pair of metal substrates;

a joining step of joining together said pair of metal substrates so that said microchannel portions confront each other, to thereby form a joined body having a flow path;

a surface processing step of forming a metal oxide film on an inner wall surface of said flow path; and

a catalyst applying step of applying a catalyst to the inner wall surface of said flow path via said metal oxide film.

37. A production method of a microreactor according to claim 36, wherein said surface processing step forms said metal oxide film by anodically oxidizing said metal substrates.

38. A production method of a microreactor according to claim 36, wherein said surface processing step forms said metal oxide film by a boehmite treatment.

39. A production method of a microreactor according to claim 36, wherein said channel portion forming step forms said microchannel portion on each metal substrate such that a section thereof becomes U-shaped or semicircular, and no angular portion exists on a wall surface along a flow

direction.

40. A production method of a microreactor according to claim 36, wherein said catalyst applying step fills the flow path of said joined body with a catalyst suspension, then removes said catalyst suspension and dries the inside of the flow path.

41. A production method of a microreactor according to claim 40, wherein said catalyst applying step gives vibration or rotation to said joined body upon drying.

42. A microreactor for obtaining hydrogen gas by reforming a feed material, characterized by comprising:

at least a plurality of unit flow path members each having a flow path inside, said flow path having one end portion serving as an inlet and the other end portion serving as an outlet, and a coupling member retaining said unit flow path members in a multi-step state,

wherein said coupling member comprises a plurality of coupling portions for tightly retaining the unit flow path members at positions where the inlets of the unit flow path members are located and at positions where the outlets thereof are located, a feed material inlet, and a gas outlet,

wherein at least one of said unit flow path members is a unit microreactor carrying a catalyst in said

flow path, and

wherein a feed material is introduced from the feed material inlet of said coupling member, and a predetermined reaction is carried out in said unit microreactor in said plurality of unit flow path members to thereby obtain desired produced gas from the gas outlet of said coupling member.

43. A microreactor according to claim 42, wherein n (n is an integer no less than two) unit flow path members are provided,

wherein said coupling portions comprise an introduction coupling portion connected to said feed material inlet, a discharge coupling portion connected to said gas outlet, and (n-1) pairs of step shift coupling portions connected to each other by an internal communication path,

wherein, with respect to the first-step unit flow path member, the inlet is coupled to and retained by said introduction coupling portion and the outlet is coupled to and retained by said step shift coupling portion,

wherein, with respect to the second-step to (n-1)th-step unit flow path members, the inlet is coupled to and retained by the step shift coupling portion connected to the prior-step step shift coupling portion by the internal communication path and the outlet is coupled to and retained by the step shift coupling portion of another

pair, and

wherein, with respect to the n^{th}-step unit flow path member, the inlet is coupled to and retained by the step shift coupling portion connected to the prior-step step shift coupling portion by the internal communication path and the outlet is coupled to and retained by said discharge coupling portion.

44. A microreactor according to claim 42, wherein said unit flow path members are detachable.

45. A microreactor according to claim 42, wherein said unit microreactor carries the catalyst on an inner wall surface of the flow path of the unit flow path member via a metal oxide film.

46. A microreactor according to claim 42, wherein said unit flow path members have the same structure, and a plurality of unit microreactors are provided so as to have different kinds of catalysts carried in the flow paths.

47. A microreactor according to claim 42, wherein the unit microreactor having a heater is provided.

48. A microreactor according to claim 42, wherein a gap for thermal insulation and/or a heat insulating material are/is interposed between the unit flow path

members of the desired adjacent steps.

49. A microreactor according to claim 42, wherein the other end portions of the plurality of unit flow path members retained in the multi-step state by the coupling member are fixed by a fixing member.

50. A microreactor according to claim 42, wherein each unit flow path member comprises a joined body in which a pair of metal substrates formed with microchannel portions for constituting the flow path are joined together such that said microchannel portions confront each other, or a joined body in which a metal cover member is joined to a surface of a metal substrate on which a microchannel portion for constituting the flow path is formed.

51. A microreactor according to claim 50, wherein said unit microreactor carries the catalyst in the flow path after forming said joined body.

52. A microreactor according to claim 50, wherein said unit microreactor carries the catalyst in the microchannel portion before the joining.

53. A production method of a microreactor for obtaining hydrogen gas by reforming a feed material, characterized by comprising:

a step of forming a microchannel portion on one surface of a metal substrate;

a step of anodically oxidizing said metal substrate to form an insulating film in the form of a metal oxide film;

a step of applying a catalyst to said microchannel portion;

a step of joining a cover member formed with a feed material inlet and a gas outlet to said metal substrate so as to cover said microchannel portion; and

a step of providing a heater on said metal oxide film on a surface, where said microchannel portion is not formed, of said metal substrate.

54. A production method of a microreactor for obtaining hydrogen gas by reforming a feed material, characterized by comprising:

a step of forming a microchannel portion on one surface of a metal substrate;

a step of applying a catalyst to said microchannel portion;

a step of joining a cover member formed with a feed material inlet and a gas outlet to said metal substrate so as to cover said microchannel portion;

a step of providing an insulating film on a surface, where said microchannel portion is not formed, of said metal substrate; and

a step of providing a heater on said insulating film.

55. A production method of a microreactor for obtaining hydrogen gas by reforming a feed material, characterized by comprising:

a step of forming, on one surface of each of a plurality of metal substrates, a microchannel portion and a through hole having an opening at a predetermined position of said microchannel portion;

a step of anodically oxidizing said metal substrates to form insulating films each in the form of a metal oxide film;

a step of applying catalysts to the microchannel portions of said plurality of metal substrates;

a step of removing said metal oxide film at a portion subjected to joining when said plurality of metal substrates are stacked in multi-steps;

a step of joining together said plurality of metal substrates so as to be stacked in multi-steps such that the microchannel portions of said metal substrates communicate with each other via said through holes, and joining a cover member formed with a gas outlet to said metal substrate located at an outermost position of the multi-steps and exposing said microchannel portion; and

a step of providing a heater on at least one of said metal oxide films located at an outermost position of

the multi-steps.

56. A production method of a microreactor for obtaining hydrogen gas by reforming a feed material, characterized by comprising:

a step of forming, on one surface of each of a plurality of metal substrates, a microchannel portion and a through hole having an opening at a predetermined position of said microchannel portion;

a step of applying catalysts to the microchannel portions of said plurality of metal substrates;

a step of joining together said plurality of metal substrates so as to be stacked in multi-steps such that the microchannel portions of said metal substrates communicate with each other via said through holes, and joining a cover member formed with a gas outlet to said metal substrate located at an outermost position of the multi-steps and exposing said microchannel portion; and

a step of providing an insulating film on a surface of at least one of said metal substrates located at an outermost position of the multi-steps, and providing a heater on said insulating film.

57. A production method of a microreactor for obtaining hydrogen gas by reforming a feed material, characterized by comprising:

a channel portion forming step of forming a

microchannel portion on one surface of a metal substrate;

a surface processing step of forming a metal oxide film on an inner wall surface of said microchannel portion;

a joining step of joining a metal cover member having a feed material inlet and a gas outlet to said metal substrate so as to cover said microchannel portion to thereby form a joined body having a flow path; and

a catalyst applying step of applying a catalyst to an inner wall surface of said flow path via said metal oxide film.

58. A production method of a microreactor for obtaining hydrogen gas by reforming a feed material, characterized by comprising:

a channel portion forming step of forming microchannel portions with patterns that are plane-symmetrical with each other, on either surfaces of a pair of metal substrates;

a surface processing step of forming a metal oxide film on an inner wall surface of each microchannel portion;

a joining step of joining together said pair of metal substrates so that said microchannel portions confront each other, to thereby form a joined body having a flow path; and

a catalyst applying step of applying a catalyst to an inner wall surface of said flow path via said metal oxide film.